11-2017

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Journal of Strength and Conditioning Research Publish Ahead of Print
DOI: 10.1519/JSC.0000000000002347

November 2017

Stature, Body Mass, and BMI in High School American Football Players: Appropriate determinants of obesity prevalence?

Short Running Title: BMI in High School in American Football Players

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ABSTRACT

The purpose of this study was to evaluate stature (HT), weight (WT), body mass index (BMI), and obesity prevalence based on BMI categories in a large sample (n = 7,175) of high school American football players enrolled as freshmen, sophomores, or juniors. Players were categorized by their positions: offensive linemen (OL), defensive linemen (DL), tight end (TE), defensive end (DE), linebacker (LB), running back (RB), quarterback (QB), defensive back (DB), and wide receiver (WR). HT, WT, and BMI increased as grade increased among all positions. OL and DL had the greatest HT, WT, and BMI ($p \leq 0.05$). Obesity prevalence was greatest in OL and DL. When accounting for age-related increases in BMI, WT increased to a greater degree than HT. If HT is an indirect indicator of skeletal size, while WT is more influenced by soft tissue, then the age-related BMI increases in the present study may be largely accounted for by soft tissue changes rather than skeletal growth. Even though obesity prevalence in OL (94.5%) and DL (78.4%) positions was greater than all other positions as determined from BMI, it is impossible to know the allocations of fat-free and fat mass—particularly in American football athletes. If obesity continues to be defined as an unhealthy accumulation of fat, then athletes who may have a greater relative proportion of lean soft tissue should not be classified as obese using BMI ($WT \div HT^2$). More sophisticated, reliable, and sensitive measure of body composition, such as skinfolds, may be more appropriate field measurements.

Key Words: athlete, health, fat-free mass

INTRODUCTION

High school American football has the highest participation numbers in the United States, with over one million high school participants in the 2015-2016 season; 99.8% of participants being males (27). American football players may also have a greater prevalence of obesity than players of other sports, including soccer, basketball, baseball, and wrestling when only considering BMI (37). This is concerning since obesity is associated with orthopedic, endocrinal, gastroenterological, pulmonary, neurological, and psychological consequences (6, 26). Obesity is also a risk factor for diseases such as type II diabetes and coronary heart disease (26, 37).

Obesity is conceptually defined as an unhealthy accumulation of fat (9). Yet the Centers for Disease Control and Prevention (CDC) define obesity as a body mass index (BMI, kg/m^2) of 30 or greater for adults, and as a BMI above the 95th percentile for that age and gender for youth (9). Counterintuitively, BMI calculations only include height (HT) and weight (WT) measurements with no direct measurement of fat mass. Simple measurements of HT and WT, while convenient, are incapable of determining fat-free and fat mass. Despite BMI being criticized as an invalid indicator of obesity (33), it continues to be used as the predominant marker of obesity.

The development of BMI as a way to determine obesity started with analyses of data from life insurance companies that contained standard values of height and weight that were considered “normal” (2). Based on the formula devised by the statistician Adolphe Quetelet:

$$BMI = \frac{WT}{HT^{2}}$$

Ancel Keys named the formula the “body mass index” and attempted to develop more globally-representative reference values to which individual BMI values could be compared by sampling men from the USA, South Africa, Italy, Finland, and Japan (2, 18). The majority of men sampled were business and professional men, not primarily athletes, suggesting that they likely had lower fat-free mass than American football players or other athletes (18). Furthermore, the references that Keys analyzed to determine the accuracy of the BMI formula included only adult men and did not study women or children (14). As children grow, their body proportions change at varying rates depending on their age, until adulthood when body proportions are more consistent (1). Since the development of Keys’ reference, different organizations, including the World Health Organization (WHO), International Obesity Taskforce (IOTF), and CDC have created their own references for different ages and genders and developed cut-offs for underweight, normal weight, overweight, and obese values (1). Thus, if BMI was originally developed and analyzed using adult men without considering athletes, women, or children, the validity of using BMI for classifying obesity in these populations may be questionable.

The BMIs of collegiate (3, 5, 28, 30) and professional (11, 19, 30) American football players have been previously reported. In collegiate American football athletes, offensive linemen (OL) and defensive linemen (DL) are reported to have the highest BMIs, which has been interpreted as a higher prevalence of obesity compared to other positions. In a cross-sectional study of collegiate American football players, Mathews et al. reported that linemen (OL and DL) are classified as obese by BMI, waist circumference, and percent body fat (24). Similarly, Bosch et al. concluded that all American football positions had healthy percentages of body fat except for OL and DL (3). Buell et al. examined anthropometric measures and blood samples of collegiate linemen and found that 49% had exhibited risk factors associated with the metabolic syndrome (5). Noel et al. showed that OL, DL, and tight ends (TE) have greater than 25% body fat and are considered borderline obese by body fat percentage (28). A meta-analysis of both collegiate and professional players by Pincivero et al. (30) also found that OL and DL have the greatest body fat percentages. Similar results have been reported for professional American football athletes (11, 19). Kraemer et al. reported the body fat percentage of OL and DL to be significantly greater than all other positions (19). Dengel et al. (11) concluded that all positions were considered lean by body fat percentage, except for OL and DL, which were classified as obese. Thus, it has been consistently demonstrated that OL and DL collegiate athletes have greater body fat percentages that other positions. While the findings of collegiate and professional American football athletes are consistent, less is known about younger American football athletes.

A few studies have examined stature (HT), weight (WT), and BMI characteristics and obesity prevalence in youth American football players as compared to their collegiate and professional counterparts. When using BMI, Malina et al. (23) found that the rate of obesity is 45% among all the positions, and OL and DL have the greatest risk for being obese in youth American football players (9 – 14 years). Laurson et al. (21) examined BMIs of high school American football linemen and reported that 45% had a BMI above the 95th percentile for their age. However, Laurson et al. (21) examined 3,683 high school linemen (OL, DL), but no other positions. The results by Malina et al. (23) and Laurson et al. (21) show a lower prevalence of obesity in young players compared to collegiate and professional American football players using BMI, but BMI may not be appropriate for assessing obesity. To illustrate, Etchison et al.

(13) examined 33,896 youth athletes and found that BMI classifications overestimate the prevalence of obesity. In fact, 62% of the subjects classified as obese by BMI were not considered obese by skinfold measurements. Mathews et al. (24) found that BMI also overestimates the prevalence of obesity in collegiate American football athletes, and Lambert et al. (20) showed that BMI overestimated body fatness and the overestimation is greater in athletes than the general population. Furthermore, the authors (20) reported that collegiate American football athletes have an average of 16 kg more fat-free mass (FFM) than matched comparison nonathletes (20). Similarly, Quiterio (31) found that adolescent boys in high-impact sports have greater total body FFM than non-athlete boys. Thus, not only is BMI unable to account for the difference between FFM and fat mass, but is also incapable of emphasizing the significant difference in FFM between athletes and non-athletes. Overall, these data suggest that BMI may incorrectly classify athletes as obese when they simply have greater FFM.

What remains unclear is whether HT, WT, or BMI, and the subsequent BMI-classified obesity prevalence are uniquely different among each player position in young American football players across different high school grades. Therefore, the purpose of this study is to further examine grade and position-specific HT, WT, and BMI in a large sample of elite high school American football athletes, while the secondary purpose is to better understand how and why these data may be inappropriate for characterizing obesity prevalence or drawing health-related conclusions in athletes.

METHODS

Experimental Approach to the Problem

A cross-sectional study design was used to examine grade- and position-related differences in HT, WT, and BMI. The prevalence of obesity in high school American football players was also calculated. Independent variables included grade level (freshmen, sophomore, junior) and position (offensive lineman [OL], defensive lineman [DL], hybrid [XX], running back [RB], quarterback [QB], defensive back [DB], and wide receiver [WR]). Dependent variables included HT, WT, and BMI.

Subjects

A database containing n = 7,888 elite high school aged male American football players containing juniors (n= 3365; height: 1.79 ± 0.07 m; mass: 88.1 ± 19.2 kg), sophomores (n=2706; height: 1.80 ± 0.08 m; mass: 85.5 ± 18.7 kg), and freshmen (n=1277; height: 1.77 ± 0.07 m; mass: 79.7 ± 17.8 kg) was transferred to the University of Nebraska-Lincoln from Zybek Sports (Boulder, CO). Seniors were excluded due to small sample size (n = 66). Participants for whom HT and/or WT were missing were excluded. Thus, only n = 7,175 male American high school football players were included in the final analysis. The database included measurements of stature (HT), body mass (WT), graduating class, and self-reported playing position. Each subject had participated in one of nine American football recruiting combines hosted by Zybek Sports between March and May 2015 in Baltimore, MD, Birmingham, AL, Austin, TX, San Diego, CA, Phoenix, AZ, Nashville, TN, Tampa, FL, Detroit, MI, and Piscataway, NJ. There were no fees to participate in any combine but the players were responsible for their own travel expenses.

Birthdates were not reported; therefore, participants were categorized by high school grade level from their graduating class. The Institutional Review Board at the University of Nebraska-Lincoln determined that this analysis did not constitute human subjects research (IRB communication, February 26th, 2016).

Initially, positions were categorized as OL, DL, TE, DE, LB, RB, QB, DB, and WR. Subsequently, however, the TE, DE, and LB position groups were combined into a hybrid group (XX) based on the procedure described in the Statistical Analyses section.

Procedures

BMI was calculated as the mass in kilograms divided by the height in meters squared (kg/m^2). Based on BMI, players were categorized as not obese (<95th percentile) or obese (≥95th percentile) according to BMI-for-age chart published by the Centers for Disease Control and Prevention (CDC) (8). Because birthdates were not reported, it was assumed that juniors were 17 years old, sophomores were 16 years old, and freshmen were 15 years old, which aligns with data from the United States Census Bureau (34). Obesity prevalence, per BMI, was calculated with the following equation for each position at each grade level.

$$\text{obesity prevalence (\%)} = \frac{\text{\# obese athletes}}{\text{\# total athletes}}$$

Statistical Analyses

All statistical analyses were performed using SPSS Statistics v.22 (Chicago, IL) and an alpha of $p \leq 0.05$ was considered significant for all analyses. Descriptive statistics including mean and standard deviation were calculated for each position and each grade as well as the total sample. Three separate two-way (3 × 7) factorial analyses of variance (ANOVA) (grade [freshman, sophomore, junior] × position group [OL, DL, XX, RB, QB, DB, WR]) were used to analyze HT, WT, and BMI. When appropriate, Tukey's Honestly Significant Difference (HSD) post hoc tests were used. Percent changes from freshmen to sophomore and from sophomore to junior were calculated for HT, WT, and BMI. Prevalence was calculated and reported descriptively.

The initial analysis showed that the BMIs of the position groups with the smallest sample sizes (TE and DE, $n \leq 135$) were not different from the LB position ($n = 1,049$), therefore these three position groups were merged into a hybrid group (XX). The outliers shown in Figure 1 represent the data that are greater than 1.5 × interquartile range.

RESULTS

Means and standard deviations (mean ± SD) by grade and position are reported in Table 1. There were no two-way (grade × position) interactions for HT, WT, or BMI ($p > 0.05$); however, there were main effects for grade and position for HT, WT, and BMI ($p < 0.001$). Significant differences are individually reported in Table 1. Obesity prevalence by grade and position is reported in Table 2. Figure 1 displays quartiles and outliers by grade and position for BMI. Percent differences in HT, WT, and BMI from freshmen to sophomore and from sophomore to junior grade levels are shown in Figure 2. Figure 3 shows the mean BMI for each position compared to the BMI-for-age percentiles chart from the CDC (8).

DISCUSSION

The primary findings of this study were that the relationships between BMI and position were consistent across grades. HT, WT, and BMI increased as grade increased among all position groups, and HT, WT, and BMI varied by position group. Independent of grade, the OL and DL groups had significantly greater BMI than all other positions. These findings are consistent with previous studies in youth (23), high school (21), collegiate (3, 5, 24), and professional American football players (11, 19). While several studies have investigated BMI in collegiate (3, 5, 20, 24, 28, 30) and professional (3, 19, 30) American football players, our study adds to the limited literature available for high school American football players. Although Malina et al. (23) and Laurson et al. (21) examined youth American football players, Malina et al. (23) studied a sample of younger children (age = 9 to 14), while Laurson et al. (21) studied only OL and DL player positions (age = 14.5 to 18.5). The strengths of our study are the examination of elite high school American football athletes and the consideration of all the player positions. Furthermore, these data are from a large, nationally-representative sample.

When determining obesity using BMI, it is important to consider the reference database to be used. The three most prominent reference databases include the CDC, International Obesity Taskforce (IOTF), and World Health Organization (WHO). The present study used the CDC guidelines and found the overall prevalence of obesity in our sample to be 32% based on BMI. The IOTF references are based on international data, and are linked to mortality rates, suggesting that IOTF cutoffs are more epidemiologically meaningful (25, 32). The IOTF guidelines define obesity according to centiles which correspond to an adult BMI of 30. According to the IOTF cutoffs, the overall prevalence of obesity in our sample would be 26%

(10). The WHO guidelines define obesity as a BMI greater than or equal to two standard deviations above the WHO growth standard median. According to the WHO cutoffs, the prevalence of obesity in our sample would be 30% (36). Monasta et al. (25) recommended that the IOTF reference may be best to identify obesity at individual and population levels in pre-school children. Keke et al. (17) also found the IOTF system to be the best reference for population studies. Nevertheless, all of these references define obesity by BMI, which does not distinguish between fat and fat-free mass. Therefore, while these high rates of obesity may appear concerning, these findings should be interpreted with caution.

The greater increases in WT relative to HT as grade increases (Figure 1) suggest that increases in BMI may be primarily associated with increases in WT, and affected minimally by HT. If HT is predominantly reflective of skeletal size, while WT is most reflective of soft-tissue mass, our findings suggest that increases in soft tissue mass may contribute more to BMI increases across grade level. In a collegiate population (age = 19 to 25 years), Lambert et al. (20) compared the FFM of American football athletes (81.3 kg) to age- and gender-matched comparisons (65.3 kg) and found that the athletes had 16 kg more FFM than the non-athletes. In adolescent males (age = 9 to 18 years), Quiterio et al. (31) found that athletes in high-impact sports have greater FFM than non-athletes by an average of 8.1 kg. Mathews et al. (24) showed that when using BMI, 67% of collegiate American football players with a healthy body fat were miscategorized as overweight or obese, and 54% of overweight players were miscategorized as obese. This evidence suggests that the greater amount of FFM in American football athletes artificially inflates obesity prevalence by skewing the BMI calculations. Our indirect finding supports the influence of soft tissue mass on BMI calculations in elite high school American football players as well.

It is possible that linemen have higher BMIs due to coaches selecting players with larger body sizes and greater strength to fill those positions. Furthermore, the prevalence of high BMIs in these groups could be additionally impacted by physiological adaptations to their specific playing demands. Bosch et al. (3) reports that OL players typically cover less distance in a game than other positions, do not need to be as fast, and are very strong, all of which are factors that contribute to a greater BMI (3).

We found the prevalence of obesity, as characterized by BMI, in the OL and DL groups (94.5% and 78.4%, respectively) was greater than all other positions (XX = 47.7%, RB = 26.6%, QB = 7.3%, DB = 3.9%, WR = 4.5%). Many studies have also found that OL and DL position groups have the greatest obesity prevalence as determined by BMI in middle school (23), high school (21), collegiate (3, 24, 30) and National Football League (NFL) (11, 19, 30) athletes. However, because these studies rely on BMI to determine obesity, it is likely the prevalence of obesity is overestimated. Body fat percentage has also been used to characterize obesity in collegiate (3, 24, 28, 30) and NFL (11, 19, 30) athletes across all the position groups. These studies also found OL and DL positions to have unhealthy amounts of body fat and rates of obesity higher than any other position groups, and that all other position groups had healthy amounts of body fat (3, 11, 19, 24, 28, 30). The high prevalence of obesity, as characterized by body fat percentage, in the OL and DL position groups suggest that players in these position groups may be at a higher risk of having unfavorable body composition. Buell et al. (5) found that more than 50% of the collegiate offensive and defensive linemen displayed metabolic syndrome and other adverse biomarkers, further suggesting that players in the OL and DL position groups may exhibit health risks. Since the data from studies using percent body fat to determine obesity indicate that OL and DL still have high obesity rates, OL and DL positions are at risk for being obese, and that the higher rates of obesity indicated by BMI are real, regardless of the flaws of using BMI to indicate obesity. Further research should consider the use of allometric scaling to account for the inherent size differences among position groups to better understand unfavorable body composition without the confounding effects of larger body sizes.

In large scale studies BMI has been shown to have error rates comparable to other methods of determining body composition, such as skinfolds and bioelectrical impedance analysis (12). While BMI may be an imperfect indicator of fatness on an individual basis, there is some support for the continued use of BMI as an indicator of body fatness and to classify obesity in the general population as some studies have found BMI and percent body fat are strongly associated (7, 15, 29). However, a number of other studies have found BMI to be a less accurate measure of body fatness than direct methods, such as dual x-ray absorptiometry (DXA) (3, 11, 20), skinfolds (4, 13), air displacement plethysmography (19), bioelectrical impedance analysis (24), hydrostatic weighing (28), and waist circumference (24). Coupled with previously stated results showing that BMI overestimates body fatness and the overestimation is greater in athletes than in non-athletes (20, 24), these collective results suggest that BMI is not an appropriate indicator of body fatness, particularly in athletic populations. Furthermore, Etchison et al. (13) found that 62% of the subjects classified as obese by BMI were false positives. It is likely, therefore, that the obesity rates reported in the present study were higher than they would be if determined from body fat measurements. For example, if the obesity rates in the OL and DL groups were 62% false positives, as suggested by the results of Etchison et al. (13), the adjusted obesity rates would be approximately 36% for OL and 30% for DL. This gross adjustment would influence the potential health-related implications for approximately n = 1,433 athletes, which is 20% of the sample. Even though this adjusted rate is lower, it is still high and may be cause for concern regarding the risk of obesity in youth high school American football athletes, particularly in the OL and DL position groups.

The results of this study indicate that as the grade of the players increases, so does the average BMI. Our findings are supported by numerous studies that have compared BMI among age groups (12, 29) or followed subjects over time (7, 15, 16). While these cross-sectional and longitudinal studies examined subjects from the general population and did not specifically examine athletes or differentiate between athletes and non-athletes, our results indicate that the same trend holds true for athletes.

Two unique aspects of our study are the population studied and the between-player differences examined. Elite high school American football players have not been studied to the same extent as collegiate and professional players. Additionally, analyzing the differences in body size among football players by position contributes to a better understanding of the player positions in elite youth American football. Furthermore, the recruiting combines took place in nine large cities across the US, making it an unusually large and nationally representative sample. By comparison, Mathews et al. (24), Kraemer et al. (19), Noel et al. (28), and Buell et al. (5) all had sample sizes of less than 100 participants. Malina et al. (23), Lambert et al. (20), Bosch et al. (3), and Dengel et al. (11) had sample sizes of less than 1,000 participants. With sample sizes of 3,683 and 33,986, respectively, Laurson et al. (21) and

Etchison et al. (13) had large sample sizes, but the sample of Laurson et al. was solely from Iowa, while the sample of Etchison et al. was solely from Georgia and Alabama. With a sample of 7,175 participants collected in 9 different cities across the U.S., our sample may be considered more nationally representative.

PRACTICAL APPLICATIONS

American football coaches should be aware of the potentially misleading nature of BMI as an indicator of health. Based on our estimates, it is possible that 20% of elite high school American football athletes in this sample were not obese, despite being categorized as obese by BMI. This would change their perceived health status and recommendations. When considering the health implications of obesity in high school American football players, coaches should measure body composition in lieu of BMI. The criterion method of measuring body composition is hydrostatic weighing, and DXA has similar errors as hydrostatic weighing (22). However, assessing obesity using skinfold measurement may be a viable, practical, and less-expensive alternative, which would constitute a direct measurement of fat mass unlike BMI. While many health concerns that are raised for American football athletes are based on the BMI calculations, coaches should be aware of the potential obesity risks for OL and DL players and the adverse health consequences of obesity.

ACKNOWLEDGEMENTS

These data were provided from a data transfer agreement through Mike Weinstein, who is the owner and CEO of Zybek Sports (Boulder, CO).

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FIGURE LEGENDS

Figure 1.

Mean BMI (×) and quartiles by grade across position groups. Outliers fall outside the interquartile range. OL = offensive lineman, DL = defensive lineman, XX = hybrid (TE, DE, and LB), RB = running back, QB = quarterback, DB = defensive back, WR = wide receiver.

Figure 2.

The percent change from freshmen to sophomore (%$\Delta 9^{th} \rightarrow 10^{th}$) grade levels and from sophomore to junior (%$\Delta 10^{th} \rightarrow 11^{th}$) grade levels.

Figure 3.

Mean BMI for position shown on top of the BMI-for-age percentiles graph derived from the CDC (8). Freshmen were assumed to be age 15, sophomores were assumed to be age 16, and juniors were assumed to be age 17. The 95^{th} percentile is the cutoff for obesity. Mean obesity prevalence by position (collapsed across grade) is shown on the left. OL = offensive lineman, DL = defensive lineman, XX= hybrid (TE, DE, and LB), RB = running back, QB = quarterback, DB = defensive back, WR = wide receiver.

Table 1.

Sample size (n). Mean height (HT), weight (WT), and body mass index (BMI) (mean ± standard deviation) by grade and position. OL = offensive lineman, DL = defensive lineman, XX = hybrid (TE, DE, and LB), RB = running back, QB = quarterback, DB = defensive back, WR = wide receiver.

Table 2.

Sample size (N), number obese (n), percent obese (X%). Obesity prevalence by grade and position. OL = offensive lineman, DL = defensive lineman, XX= hybrid (TE, DE, and LB), RB = running back, QB = quarterback, DB = defensive back, WR = wide receiver.

Table 1. Sample size (n). Mean height (HT), weight (WT), and body mass index (BMI) (mean ± standard deviation) by grade and position. OL = offensive lineman, DL = defensive lineman, XX = hybrid (TE, DE, and LB), RB = running back, QB = quarterback, DB = defensive back, WR = wide receiver.

		Grade			Position Totals*
		Freshmen	Sophomore	Junior	
OL	n	75	204	382	661
	HT[a]	1.81 ± 0.07	1.83 ± 0.07	1.85 ± 0.07	1.83 ± 0.07
	WT[a]	112.2 ± 18.8	117.1 ± 19.1	121.8 ± 16.9	117 ± 18.1
	BMI[a]	34.1 ± 5.3	34.8 ± 5.0	35.5 ± 4.7	35.1 ± 4.9
DL	n	105	263	470	838
	HT[b]	1.81 ± 0.06	1.82 ± 0.07	1.83 ± 0.06	1.82 ± 0.06
	WT[b]	101.8 ± 18.2	106.8 ± 17.7	109.8 ± 17.3	106.1 ± 17.7
	BMI[b]	31.2 ± 5.6	32.5 ± 5.6	32.9 ± 5.7	32.6 ± 5.7
XX	n	180	391	606	1177
	HT[d]	1.77 ± 0.06	1.79 ± 0.06	1.8 ± 0.06	1.79 ± 0.06
	WT[c]	83.3 ± 10.7	88.5 ± 10.4	91.8 ± 10.3	87.9 ± 10.8
	BMI[c]	26.5 ± 3.1	27.7 ± 3.2	28.2 ± 3.1	27.8 ± 3.2
RB	n	224	392	536	1152
	HT[g]	1.72 ± 0.06	1.72 ± 0.06	1.74 ± 0.06	1.73 ± 0.06
	WT[d]	73.8 ± 10.7	77.1 ± 9.8	81.2 ± 9.6	77.4 ± 10.3
	BMI[d]	25 ± 3.3	26 ± 2.8	27 ± 2.9	26.3 ± 2.9
QB	n	124	225	255	604
	HT[c]	1.78 ± 0.06	1.8 ± 0.06	1.82 ± 0.06	1.8 ± 0.06
	WT[d]	72.8 ± 8.5	78.5 ± 8.9	81.9 ± 9.3	77.8 ± 9.6
	BMI[e]	23.1 ± 2.4	24.1 ± 2.3	24.6 ± 2.5	24.1 ± 2.5
DB	n	187	423	675	1285
	HT[f]	1.72 ± 0.06	1.75 ± 0.06	1.76 ± 0.06	1.75 ± 0.06
	WT[f]	68.3 ± 9.3	72.2 ± 7.5	75 ± 8.4	71.8 ± 8.5
	BMI[e]	22.9 ± 2.7	23.7 ± 2.3	24.1 ± 2.5	23.8 ± 2.5
WR	n	226	502	730	1458
	HT[e]	1.76 ± 0.07	1.78 ± 0.07	1.8 ± 0.07	1.78 ± 0.07
	WT[e]	70.9 ± 9.5	74.6 ± 10	77 ± 9.4	74.1 ± 9.9
	BMI[e]	22.7 ± 2.6	23.6 ± 2.3	24 ± 2.5	23.7 ± 2.5
Grade Totals*	n	1121	2400	3654	7175
	HT	1.76 ± 0.07	1.77 ± 0.07	1.79 ± 0.07	1.78 ± 0.07
	WT	78.9 ± 17.4	84.4 ± 18.5	88.9 ± 19.5	85.8 ± 19.2
	BMI	25.4 ± 4.8	26.6 ± 5.0	27.6 ± 5.3	26.9 ± 5.2

* Indicates a main effect on HT, WT, and BMI.
[a] Greater than b, c, d, e, f, g, and h. [b] Greater than c, d, e, f, g, and h. [c] Greater than d, e, f, g, and h.
[d] Greater than e, f, g, and h. [e] Greater than f, g, and h. [f] Greater than g and h. [g] Greater than h.

Table 2. Sample size (N), number obese (n), percent obese (X%). Obesity prevalence by grade and position. OL = offensive lineman, DL = defensive lineman, XX= hybrid (TE, DE, and LB), RB = running back, QB = quarterback, DB = defensive back, WR = wide receiver.

		Grade			Position
		Freshmen	Sophomore	Junior	Totals
OL	N	75	204	382	661
	n	69	192	364	625
	(X%)	(92.0%)	(94.1%)	(95.3%)	(94.5%)
DL	N	105	263	470	838
	n	75	213	369	657
	(X%)	(71.4%)	(81.0%)	(78.5%)	(78.4%)
XX	N	180	391	606	1177
	n	81	189	292	562
	(X%)	(41.7%)	(48.3%)	(48.2%)	(47.7%)
RB	N	224	392	536	1152
	n	53	96	158	307
	(X%)	(23.7%)	(24.5%)	(29.5%)	(26.6%)
QB	N	124	225	255	604
	n	13	13	18	44
	(X%)	(10.5%)	(5.8%)	(7.1%)	(7.3%)
DB	N	187	423	675	1285
	n	10	21	19	50
	(X%)	(5.3%)	(5.0%)	(2.8%)	(3.9%)
WR	N	226	502	730	1458
	n	9	27	30	66
	(X%)	(4.0%)	(5.4%)	(4.1%)	(4.5%)
Grade Totals	N	1121	2400	3654	7175
	n	310	751	1250	2311
	(X%)	(27.7%)	(31.3%)	(34.2%)	(32.2%)

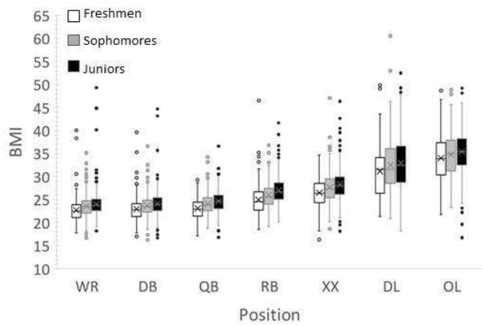

Figure 1. Mean BMI (×) and quartiles by grade across position groups. Outliers fall outside the interquartile range. OL = offensive lineman, DL = defensive lineman, XX = hybrid (TE, DE, and LB), RB = running back, QB = quarterback, DB = defensive back, WR = wide receiver.

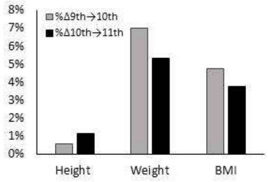

Figure 2. The percent change from freshmen to sophomore (%Δ9th→10th) grade levels and from sophomore to junior (%Δ10th→11th) grade levels.

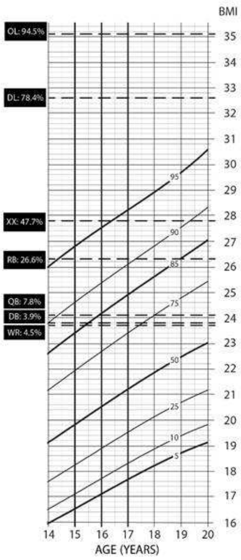

Figure 3. Mean BMI for position shown on top of the BMI-for-age percentiles graph derived from the CDC (8). Freshmen were assumed to be age 15, sophomores were assumed to be age 16, and juniors were assumed to be age 17. The 95th percentile is the cutoff for obesity. Mean obesity prevalence by position (collapsed across grade) is shown on the left. OL = offensive lineman, DL = defensive lineman, XX= hybrid (TE, DE, and LB), RB = running back, QB = quarterback, DB = defensive back, WR = wide receiver.